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Explaining climate policies' popularity—An empirical study in four European countries

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ABSTRACT

The climate change mitigation potential of the production side has been discussed very frequently, but private citizens and households have received less systematic attention. Thus, this paper focuses on the willingness of private households to reduce their greenhouse gas emissions. While many scholars study the socio-economic characteristics of people to then recommend policies, we change the analytical perspective and look at the characteristics of climate mitigation actions that affect households' willingness to adopt these measures: Costs, emission reductions, behavioral change, and consumption sector.

The paper uses data from HOPE (*HOusehold Preferences for reducing greenhouse gas emissions in four European high-income countries*), an interdisciplinary project investigating households' preferences for reducing greenhouse gas in four countries (France, Germany, Norway and Sweden). We use a fuzzy-set QCA (fsQCA) to analyze which attributes are necessary or sufficient conditions for specific actions to be selected by participants of HOPE.

The results of the fsQCA show that *Food & Recycling* actions are particularly popular. The general pattern that was found shows that people prefer actions that are easy to implement even though they often do not reduce the CO2e-Footprint by much. Therefore, the condition *Behavioral Change* is the most important lever in improving households' willingness to act on climate change. Moreover, the analysis of *Health Information* suggests that there is an urgent need to go beyond financial arguments in future research.

1. The contribution of household consumption to national CO_2e-emissions

At the 21st Conference of Parties to the United Nations Framework Convention on Climate Change, member states agreed to the goal of limiting global warming to 2.0 °C of pre-industrial levels and to strive for 1.5 °C. To reach this goal, every sector of society has to reduce its greenhouse gas (GHG) emissions. Increasingly attention is devoted to the fact that households are directly or indirectly responsible for a large portion of high-income countries' GHG-emissions (Dietz et al., 2009; IPCC, 2014). They play a key role if rich countries want to reach their nationally determined contributions (NDC) (e.g. Millar et al., 2017; IPCC, 2014: 66; Rogelj et al., 2015). The industry's mitigation potential has been discussed very frequently, but private citizens and households have received less systematic attention. At the same time, poverty alleviation leads to higher GHG-emissions for households from low- and middle-income economies (Rosa and Dietz, 2012; Sadorsky, 2014; Tilman and Clark, 2014). This paper focuses on climate change mitigation actions that are available to households to reduce their CO_2-equivalents (CO_2e) footprint.

The analysis addresses the question: What attributes of mitigation actions lead households to select them? Qualitative Comparative Analysis (QCA) was used, specifically fuzzy-set QCA (fsQCA). It has been suggested that "[e]nvironmentally significant behavior depends on a broad range of causal factors, both general and behavior-specific. A general theory of environmentalism may therefore not be very useful for changing specific behaviors" (Stern, 2000: 421; Whitmarsh, 2009: 22). QCA can make a valuable contribution to solving this puzzle because it structures and analyses problems differently than traditional research approaches. Charles Ragin argued that, "[w]hen an outcome results from several different combinations of conditions; it is not easy to identify the decisive causal combinations across a range of cases, especially when the patterns are confounded" (1987: 20). QCA works under the assumption of equifinality, allowing researchers to test for conjectural causation when comparing cases. Different combinations of conditions can result in the same outcome. This perspective helps

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understand empirical observations that are difficult to explain with more established methods while retaining the ability to compare a large number of cases in a more concise fashion than individual case studies. In addition, the majority of studies investigated the socio-economic or psychological characteristics of individuals (e.g. Tanner, 1999; Lorenzoni et al., 2007; Bichard and Kazmierczak, 2012; Drews and van den Bergh, 2016). The present study analyses specific climate mitigation actions and their attributes, approaching the issue of policies' popularity from a new perspective.

The paper is based on data gathered for an interdisciplinary investigation into *HOusehold Preferences for reducing greenhouse gas emissions in four European high-income countries* (HOPE) (Herrmann et al., 2017). 309 households were interviewed between June and November 2016 in one city per country (Communauté de Pays d'Aix, France; Mannheim, Germany; Bergen, Norway; Umeå Sweden). The participating households were presented with up to 65 action-cards that included information on the reduction of CO_2e-emissions in kilogram per year and costs or savings of actions. Lastly, half the participants received information on the health effects of specific actions. Per household, one member rated these climate-change-mitigation actions on a five-item Likert scale in the consumption sectors *Food & Recycling*, *Housing*, *Other Consumption*, and *Mobility*.

The paper is divided into five sections. We first present a summary of the theoretical literature on the determinants of mitigation behavior. Then, we describe QCA as a method. This is followed by description of the data collection and the data used. Afterwards, the calibration process will be outlined. The next two parts present the results of the fuzzy-set-QCA and discuss the findings followed by the conclusion.

2. Theoretical background

Many disciplines have contributed to our understanding of how individuals perceive climate change and act, or do not act, to mitigate it. In a large overview of the literature on public policy and climate change, three concepts emerged that are relevant when studying climate policy: 1) Socio-political factors and perceptions of climate change; 2) perceptions of climate policies; and 3) contextual factors (Drews and van den Bergh, 2016).

Psychological studies have demonstrated that household's willingness to reduce emissions may depend on several factors: cutting emissions, costs or savings, health benefits, or feasibility. A study on car use by Swiss consumers showed that perceived barriers significantly reduced the willingness to engage in mitigation behavior (Tanner, 1999 153). Others found that respondents were most willing to accept low-cost climate-friendly behaviors, but that the perceived climate-friendliness of the low-cost behavior is most important for predicting respondents' willingness (Tobler et al., 2012). In a Basque sample, respondents were on average willing to pay 132 Euros to support energy efficient measures at home (Longo et al., 2012). But in a sample of homeowners in England and Wales, over a third were not willing to pay anything for energy-saving measures in their home. However, over ten percent were willing to pay over 1000 pounds to render their houses more energy-efficient (Bichard and Kazmierczak, 2012). Simply focused on economic arguments seems too simple of an answer (Gowdy, 2008). Among members of the UK public, a significant barrier to taking action on climate change was meaningful changes to behavior (Lorenzoni et al., 2007). Residents of Hampshire reduced energy consumption at home or during travels mostly for non-environmental reasons, such as saving money or fostering health (Whitmarsh, 2009). The HOPE-project itself contributes the perspective that health may be a factor in encouraging more climate-friendly behavior. By using the actions and not the households as units of analysis, we can contribute to the debate on what factors make policies feasible in the eyes of the public.

2.1. How the conditions influence the household's willingness to adopt a climate mitigation action

As described in the introduction, different factors influence people's willingness to adopt climate mitigation actions. This analysis focused on four of these conditions.

The first factor, the *Economic Benefit* of an action, referred to whether or not households saved money with the mitigation actions they selected. From an economics perspective, people should have rationally maximized their advantages when selecting actions (e.g. Buchanan and Tullock, 1962; Kirchgässner, 2014). Given specific constraints, they should try to optimise utility. They are also cognisant of their intentions. Thus, they should choose actions that come closest to their intentions given specific constraints (Kirchgässner, 2013). In the HOPE-study, households had to choose climate mitigation actions to halve their current CO_2e-emissions by 2030. If people's intentions were determined by economic factors, households should have chosen actions that maximized savings. In this case, the benefits of an action would be described by the formula:

$$E_i \Rightarrow B_i$$

B_i stood for a person's whole benefit and E_i for the cost savings of an action. Studies have shown that people's intentions are not only driven by economic factors (e.g. Tanner, 1999; Tobler et al., 2012).

Proceeding beyond classical economic arguments, other motivations appear to co-determine people's intentions (Gowdy, 2008; Homans, 1961). Thus, values like climate protection or biodiversity could have driven choices. In this case, the *CO_2e-Reduction* (CO_i) potential would be important for the willingness to choose a mitigation action. A combination of factors can drive intentions.

$$E_i \vee CO_i \Rightarrow B_i$$

The third factor covers the necessity and the strength of a *Behavioral Change* when carrying out an action. For example, switching from a conventional car to an electric car requires limited behavioral change by still providing the means to travel longer distances quickly. But giving up your car completely will require more adjustments on a larger scale. It may involve more planning for trips and more dependence on services provided by others. Thus, behavioral change could be a factor in determining people's intentions to act climate friendly (e.g. Tobler et al., 2012). We include it as BC_i in the formula:

$$E_i \vee CO_i \vee \neg BC_i \Rightarrow B_i$$

Previous research demonstrated that health could be an important argument for mitigation. Some mitigation actions have a positive impact on people's health. If they implemented them, they could potentially increase their life expectancy and quality. There are differences in the strength of health effects of actions, just like there are differences in the savings, behavioral change required, or CO_2e-reductions achieved. An increased life expectancy could also influence intentions (Whitmarsh, 2009). The *Health Effect is* included as HB_i:

$$E_i \vee CO_i \vee \neg BC_i \vee HB_i \Rightarrow B_i$$

The formula above assumed that everyone reacts equally to every attribute of climate mitigation actions. However, it is reasonable to expect that the importance of a specific condition could differs from person to person. Thus, the condition I*j*, is included. It would cover importance each household could put on any of the conditions presented above.

$$I_{1j}{*}E_i \vee I_{2j}{*}CO_i \vee I_{4j}{*}HB_i \wedge I_{3j}{*}BC_i \Rightarrow B_i$$

Individual characteristics like socioeconomic status or socialisation would determine I*j*. How important these individual characteristics of households are is not the question at hand here. This paper is an exploratory analysis of the question: *What attributes of mitigation actions lead households to select them?* If the QCA-results presented researchers

with one or more sufficient solution paths for the occurrence of a *High Willingness to Implement an Action*, then policy-makers would have to consider this solution path when designing of mitigation policies for households.

Based on existing research, households should select mitigation actions that accrue high *Economic Benefits*, a high *CO_2e-Reduction* and *Health Benefits* but do not require strong *Behavioral Change*. However, this combination of attributes is very rare in current mitigation actions available to households. Thus, people should prefer one or two factors or a combination of the factors. The question was: Which of the actions' attributes did our households favour?

In addition to the attributes listed in the formula, we included four dummy conditions that cover the each actions consumption sectors as conditions. We do not have theoretical assumptions about these conditions. Nevertheless, it is possible that people are more willing to adopt actions that belong to *Mobility* instead of *Food & Recycling* or *Other Consumption* and it is possible that people preferred different conditions within a single consumption sector.

2.2. Qualitative Comparative Analysis

QCA helps its users understand social phenomena in ways that differ substantially from traditional quantitative or qualitative approaches (e.g. Ragin, 1987: 2f; Schneider and Makszin, 2014: 449). Instead of focused on the influence of one variable or an in-depth study of a single case, QCA treats cases as combinations of attributes (Fiss, 2011: 401). For example, modernization theory predicts that high-income countries democratize while low-income countries do not. However, there are low-income countries that democratized (e.g. Burundi, Mali, or Zambia). The set-relational perspective suggests that a condition's effect on the outcome may differ depending on the combination of conditions of a specific case. The perspective is deterministic, not probabilistic. The idea of complex outcomes is fundamental to QCA. Different causal conjectures can lead to the same result – equifinality (Marx et al., 2014: 120). It also implies that absent conditions or combinations do not necessarily lead to the absence of an outcome – asymmetry (Fiss, 2011: 394).

The most popular versions are crisp- and fuzzy-set QCA (csQCA / fsQCA).[1] Both deal with subset relations to identify necessary and sufficient condition for the occurrence of an outcome (Schneider and Wagemann, 2012: 13; Marx et al., 2014: 124).[2] Set-membership scores between 0 (non-membership) and 1 (full-membership) are used to describe if cases present attributes and a result. Assigning membership scores allows researchers to use truth tables to display information and compare cases concisely. Solution terms present researchers with a good overview over different combinations of conditions (Schneider and Wagemann, 2010: 404).

2.3. Data description

This paper analyzes data from HOPE. The full study protocol of the HOPE research project is described by Herrmann et al. (2017). From June to November 2016, the HOPE-Team interviewed 309 households in four cities: Communauté-de-Pays-d'Aix (France), Mannheim (Germany), Bergen (Norway), and Umeå (Sweden). The households rated individual climate change mitigation actions in four sectors of CO_2e-emissions: *Food & Recycling*, *Housing*, *Mobility* and *Other Consumption*. The climate change mitigation actions were presented on action cards. These action cards described the mitigation action and contained three additional information boxes. First, they informed the households how much CO_2 equivalents in kilogram per year the household could save if they implemented the action. Second, they informed the household about monthly savings/expenses in Euro (or Norwegian/Swedish Kronor). Third, half of the households received information on what effect the mitigation measure would have on the households' health. While this did not mean that the households without the *Health Information* could not have known about these effects, the idea was that pointing out the health impacts could influence their rating of actions.

The CO_2e-savings and each households' financial costs/savings were calculated individually. The HOPE-team gathered the base data through a detailed questionnaire about their consumption habits, income and expenditure before interviewers visited them. The information on the cards was individualized based on the online questionnaire before the interview. Interviewers presented households with their initial carbon footprint and the action cards (Herrmann et al., 2017: 5).

The *Health Information* was not individualized. 11 out of 65 actions had an immediate positive health effect, ranging from moderate to high, one action had a negative health effect and 53 actions did not have a proven immediate health effect. 'Immediate' refers to health effects that people would experience personally and directly even if other people chose not to mitigate.

Before households received the action cards, interviewers instructed them to, "Imagine you would be required to reduce your carbon footprint by 50% by 2030. To reach this goal, how willing are you to implement the following actions." Then, households rated the action-cards on a five-item Likert scale from 1 = very willing to 5 = not willing. Up to 65 action cards were available. Depending on the household, some actions were not applicable and coded as such. For instance, a vegetarian household did not have the option to reduce meat consumption.

2.4. Calibration of conditions and outcome

The calibration process is one of the most important parts of any QCA. During the data calibration, it was important to remain transparent about how variables were transformed into membership scores between 0 and 1.

"In order to be analytically fruitful, calibration requires the following: (a) a careful definition of the relevant population of cases; (b) a precise definition of the meaning of all concepts (both the conditions and the outcome) used in the analysis; (c) a decision on where the point of maximum indifference about membership versus non-membership is located […]" (Schneider and Wagemann, 2012: 32).

The willingness of participants to adopt a climate mitigation action was the outcome based on the Likert scale presented during the interview. Eight conditions were used for the analysis. 1) the *Economic Benefit*/cost of a climate mitigation action; 2) the *CO_2e-Reduction* of an action; 3) the degree of *Behavioral Change* that it required; 4) and if households received *Health Information*. Conditions 5–8 were dummies for the consumption sectors *Food & Recycling*, *Housing*, *Mobility*, and *Other Consumption*. Table 1 summarizes the calibration.

2.4.1. Outcome: rating mitigation actions

The action cards' five-item Likert scale ratings were used to calculate the outcome as can be seen in Table 1. The Likert score 5 became the set-membership score 0, the Likert score 4 turned into 0.25 and so on. Thus, all participants who rated an action with a Likert score of 1 were full members of the subset 'willing to implement the action'. In the Models reported here, the Likert scores of 3 were coded as missing because there was no way of knowing if a person was part of the subset 'willing to implement the action' or not based on the data available. To make sure that other options were considered, robustness tests were conducted with Likert scores of 3 coded as 0.4 or 0.6 (see Tables A5 and A6). Results did not change substantially.

2.4.2. Condition 1: economic benefit of an action

The monthly costs or savings for every mitigation action were

[1] Marx et al., 2014 offer a good short introduction to the method. For detailed explanations of QCA see Ragin, 1987 or Schneider and Wagemann, 2012.

[2] The outcome is comparable to the dependent variable and the conditions are the independent variables.

Table 1
Calibration of outcome and conditions.

Outcome & Conditions	Method of calibration	Fuzzy-Set-Values
Outcome: *Willingness to Implement an Action*	Indirect	0 = 5 not willing 0.25 = 4 0.5 = 3 (coded as missing) 0.75 = 2 1 = 1 very willing
Condition 1: *Economic Benefit*	Direct	Threshold 0 = 0 0.5 = -0.05 1 = -1.6
Condition 2: *CO_2e-Reduction*	Direct	Threshold 0 = 0 0.5 = -1.34 1 = -5.46
Condition 3: *Behavioral Change*	Indirect	0.1 = action replaces 0.6 = action reduces 1 = action renounces
Condition 4: *Health Information*	Indirect	0 = households did not get *Health Information* 1 = households received *Health Information*
Condition 5: *Household*	Indirect	0 = action of another category 1 = action of the category *Household*
Condition 6: *Food & Recycling*	Indirect	0 = action of another category 1 = action of the category *Food & Recycling*
Condition 7: *Mobility*	Indirect	0 = action of another category 1 = action of the category *Mobility*
Condition 8: *Other Consumption*	Indirect	0 = action of another category 1 = action of the category *Other Consumption*

calculated based on the responses from the initial survey. The absolute cost reduction per month might not be very meaningful when comparing households because of variations in income. Therefore, the analysis included a condition that showed the cost reduction of an action as percent of a household's monthly income.

Because of the high number of cases, it was impossible to have detailed information about all of them and there is no straightforward theoretical argument for calibration. Therefore, the condition was calibrated directly (Schneider and Wagemann, 2012: 35ff.). This means that cut-off points mirrored large drops observed in the distribution of the relative costs/savings (Fig. 1).

2.4.3. Condition 2: CO_2e-Reduction

The condition *CO_2e-Reduction* was calibrated directly as well. A variable was calculated that included the reduction of all actions as percent of the initial CO_2e-footprint of each household. Again, drops in the distribution served as the basis for cut-offs for the set-membership scores (Fig. 2).

2.4.4. Condition 3: behavioral change

Behavioral Change generally described the degree to which households would have to change their current consumption behavior. It was divided into three categories that indicated how meaningful behavioral hurdles for the realization of an action were. The first category only required households to 'replace' a household item with something that offered equal services with lower GHG-emissions, e.g. buy a more energy efficient TV. These actions should have been the most popular because it was not necessary to change consumption behavior. There are of course differences in degree (i.e. more expensive replacements like buying an electric car). These actions had a fuzzy-set score of 0.1.

The second category of actions required households to reduce an activity. It included actions that lead to a reduction of climate-unfriendly behavior like flying or using a car. All actions in this category were set at the value 0.6, because participants needed to change their current behavior to some degree. Intercontinental vacations might have to be cut or planned differently if a household reduced flights. However, they did not need to renounce these things completely.

The third category included actions that made households 'renounce' a specific behavior completely, e.g. stop using a personal car (car sharing was still possible).These actions required substantial adaptation in everyday behavior from households to find new routines. Thus, these actions got the membership score of 1.

2.4.5. Condition 4: health information

The HOPE-team

> "estimated the individual health impact of each mitigation measure in terms of quality adjusted life years (QALYs). QALYs are computed by examining the effect on age-specific mortality from the change in exposures or health-related behaviors associated with an estimate of the decrease in the quality of life for the additional years lived with a disease or disability" (Herrmann et al., 2017: 8).

The estimation of the health co-benefits was based on published results for the United Kingdom. They classified the impact on life expectancy using five categories: "[no effect]; −1 month, < +1 month (small effect); +1–3 months (moderate effect); and > +3 months (substantial effect); [as well as > + 0 months (negative effect)]" (Herrmann et al., 2017: 8–9).

The *Health Information* described above was transformed into a dummy-condition. If a household received *Health Information*, their membership score was set to 1. Households that did not receive *Health Information* had a membership score of 0.

2.4.6. Conditions 5–8: dummy-conditions for consumption sectors

The last four conditions were dummy-conditions for the consumption sectors *Food & Recycling*, *Housing*, *Mobility*, and *Other Consumption*. Whenever an action has a value of 1 for one action it automatically has a value of 0 for the other three sectors. In other words, an action could only be part of one dummy-condition. For example if an action had a value of 1 for the dummy-condition *Household*, the action is uniquely and exclusively part of the category *Household*. Table 1 offers a summary for the calibrations of all conditions and the outcome.

3. QCA and results

R and the R-package "QCA" were used to run the analysis (Dusa,

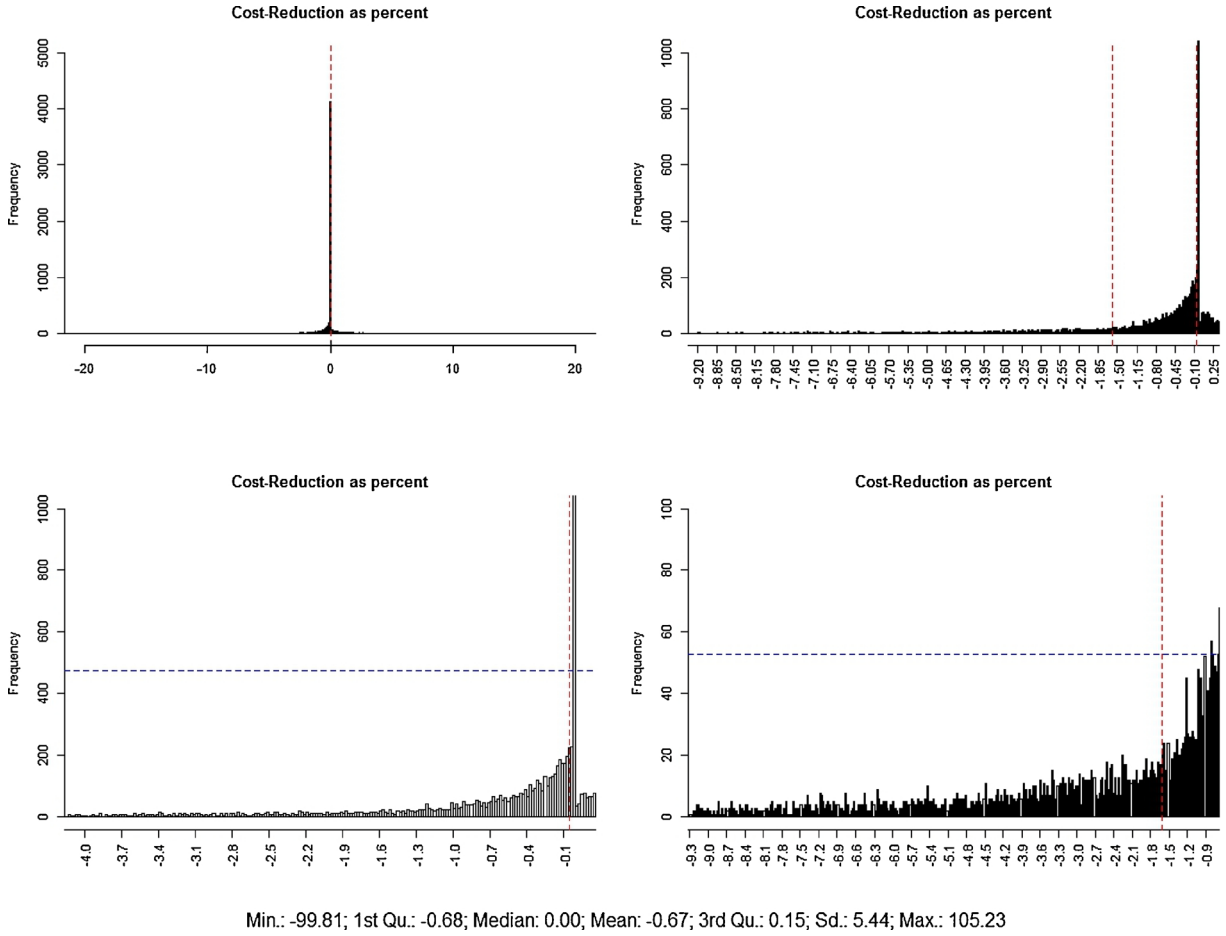

Fig. 1. Distribution of actions' cost reduction.
Note: Fig. 1 shows the cost-reduction of the actions as percent of the household's monthly income. The four diagrams visualize the same distribution but at different scaling.
Source: Own calculation based on HOPE data.

2018). As was highlighted in the methods section, a QCA requires consistency values for sufficient and necessary conditions. The consistency levels of 0.75 for sufficient conditions and the consistency value of 0.9 for necessary conditions are commonly used (Schneider and Wagemann, 2010: 406). After consulting, the truth table (Appendix; Table A1) it was decided to use the consistency value 0.74 for sufficient conditions and a consistency value of 0.9 for necessary conditions. Using 0.74 instead of the usual 0.75 as threshold for sufficiency was based on three arguments. First, in a large-*N*-design consistency values of the analysis tend to be lower (Greckhamer et al., 2013, pp. 61–65). Second, the truth table contains a solution path that has a consistency close to 0.75 (0.747) that includes 1324 observations. Third, the PRI-value of 0.682 was quite high. The solution path was included in the minimization process based on best practices for QCA. To avoid that one household alone could lead to a solution path, the frequency threshold was set to 66 actions. This decision was based on the fact that each household could rate up to 65 action cards.

The analysis was split in two sections. First, the whole sample of actions was analyzed for all participants (Model 1). Not all households received information about the health effect of the actions. Thus, the health effect condition was excluded from this model. As a complement, Model 2 only included actions that had a health effect, thus including the condition *Health Information*. The intention behind Model 2 was to answer the question if *Health Information* determined households' *Willingness to Implement an Action*.

For the entire sample, no single condition was necessary for the occurrence of the outcome. Table 2 shows the sufficient solution path for the whole sample (11,841 observations). The complex, parsimonious, and intermediate solution paths were identical for sufficient conditions.

The solution path (P1) shows that households were very willing to implement an action if it did not offer *Economic Benefits*, did not necessitate strong *Behavioral Change,* and was part of the category *Food & Recycling*. The path has a raw coverage of 0.244, it applies to 1872 observations. 75.5 percent of these observations are consistent which means that this solution path explains 75.5 percent of the observations.[3]

The condition Food & Recycling was exclusive. The solution term refers only to actions in the consumption category *Food & Recycling*. The same is true for the other dummy conditions (*Household, Mobility and Other Consumption*). As will be shown below, including these mutually exclusive conditions in Model 1 of the QCA led to the same results as if a subsample analysis for each of the four consumption categories was run (*Food & Recycling, Household, Mobility and Other Consumption)*.

However, the model shows that the other categories did not display general patterns (*Household, Mobility and Other Consumption*). In accordance with Meuer et al., 2015, a one-sample-*t*-test was run to further analyse if people were more willing to adopt actions of the *Food & Recycling* category.

[3] The consistency is not a percentage value. To calculate the percentage of cases explained by a solution path the explained observations must be shared by all observations the solution path includes.

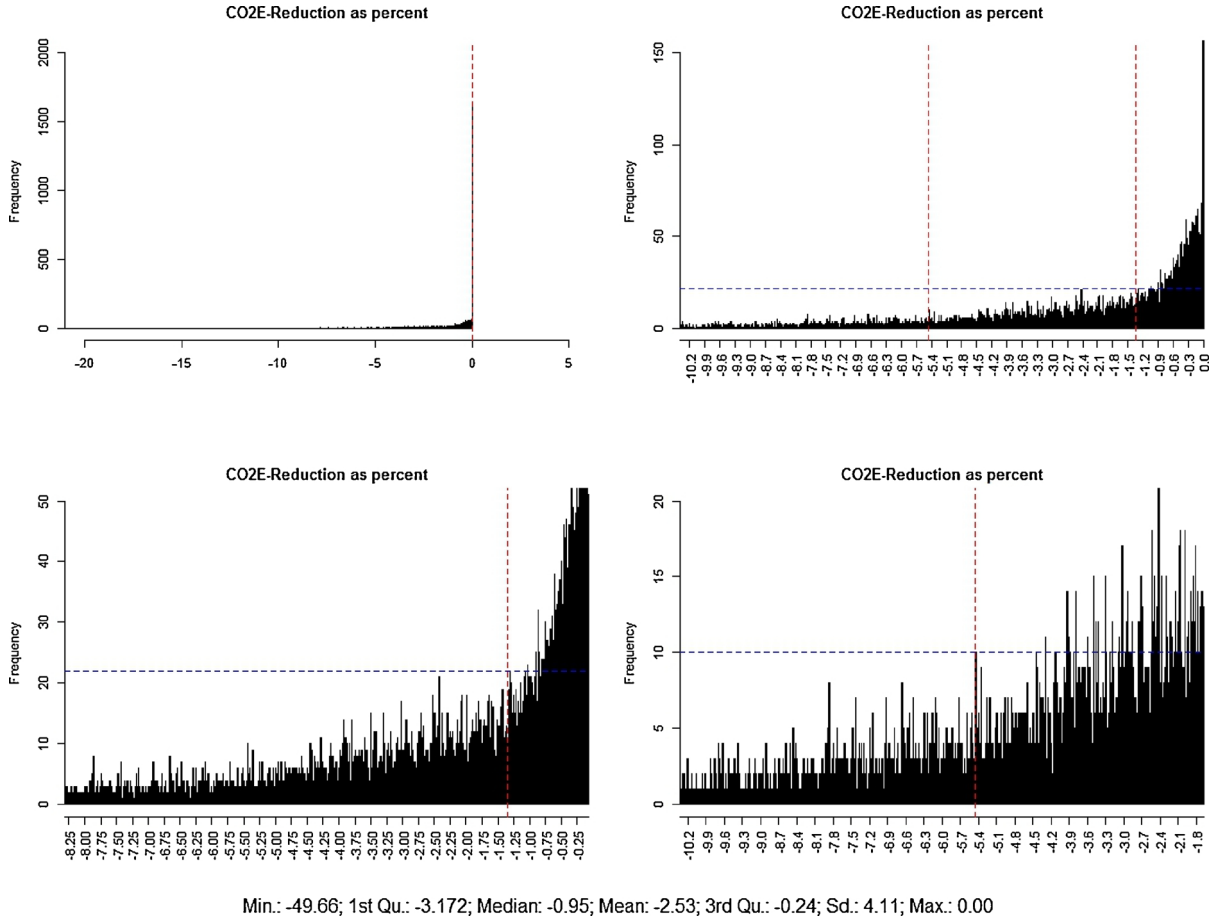

Fig. 2. Distribution of actions' CO2e-Reduction.
Note: Fig. 2 shows the CO2e-Reductions of the actions as percent of the household's initial footprint. The four diagrams visualize the same distribution but at different scaling.
Source: Own calculation based on HOPE data.

Table 2
Model 1 – solution path for the whole sample (N = 11,841).

	Solution
	P1
Attributes of actions	
Economic Benefit	⊕
CO2e-Reduction	
Behavioral Change	⊕
Control Variables	
Household	⊕
Food & Recycling	●
Mobility	⊕
Consumption	⊕
Covered Obersvations	1872
Consistent Cases	75.48%
Consistency	0.75
PRI-Value	0.70
Raw Coverage	0.24
Overall Solution Coverage	**0.75**
Overall PRI-Value	**0.70**
Overall Solution Coverage	**0.24**

Note: Black dots indicate the absence of a condition and circles with an "┼" indicate its presence (e.g. Fiss 2010).

The results of the *t*-test are displayed in Table 3. When the analysis was limited to actions from the *Food & Recycling* category, participants on average demonstrated a significantly higher willingness for implementation (64.1 percent) in comparison to the analysis that included all actions (50.4 percent). A logistic regression model supports this finding (Appendix; Table A2). Additionally the *t*-test shows that there were significant differences between the *Food & Recycling* actions and the other conditions. For example, only 33.3 percent of the Food actions made behavioral change necessary versus 45.3 percent for the entire sample. The authors also compared the means of the *Food & Recycling* subsample with the subsample of P1 from Table 2. The observations included in P1 had a higher *Willingness to Implement an Action* (75.5 percent), which is 11.4 percentage points more than for the *Food & Recycling* subsample and 24.8 percentage points higher than for the entire sample. It follows that *Food & Recycling* had an effect on the willingness but not all of the variance could be attributed to this single condition. It was the combination of conditions in the solution path that lead to higher willingness for mitigation. No action in P1 provided economic benefits. Moreover, there was no condition that required extreme behavioral change. For the entire sample, 50.7 percent of actions led to economic benefits and for the Food & Recycling subsample 38.6 percent accrued savings. The same is true for behavioral change. In the full sample 45.3 percent of actions necessitated Behavioral Change. Only 33.33 percent of actions in the subsample Food & Recycling required Behavioral Change.

Because the dummy-conditions were mutually exclusive a separate QCA was run for every consumption category. The QCA for the *Food & Recycling* actions lead to the same solution path as in Model 1(Appendix; Table A3). At the same time, the coverage of the solution paths is higher because there are fewer observations. It is clear that the solution paths could only cover actions that are part of the Food &

Table 3
t-test for independent samples.

Conditions	Entire sample	Household		Food & Recycling		Mobility		Other Consumption		Solution Path	
	Mean	Mean	Diff.	Mean	Diff.	Mean	Diff.	Mean	Diff.	Mean	Diff
Willingness	0.507	0.460	−0.048***	0.641	0.134***	0.427	−0.080***	0.482	−0.025	0.755	0.248***
											0.114***
Economic Benefit	0.507	0.419	−0.088***	0.386	−0.121***	0.706	0.199***	0.568	0.061***	0.000	0.507
											0.307
CO2e-Reduction	0.472	0.437	−0.035***	0.699	0.226***	0.743	0.271***	0.105	−0.367***	0.707	0.235***
											−0.008
Behavioral Change	0.453	0.488	0.035***	0.333	−0.120***	0.452	0.001	0.533	0.080***	0.000	0.453
											0.333

*p < 0.1.; **p < 0.05; ***p < 0.01.
Note: Table 3 shows the difference in means between the entire sample and the groups of actions that belong to the four consumption categories. It also includes the actions that belong to a solution path. The mean is based on the observations with a fuzzy-set value above 0.5.

Table 4
Model 2 – solution paths for the subsample only includes actions with health indicator (N = 1935).

	Solution	
	HP1	HP2
Attributes of actions		
Economic Benefit	⊕	●
CO2e-Reduction	⊕	⊕
Behavioral Change	⊕	⊕
Health Information	⊕	●
Control Variables		
Household	⊕	⊕
Food & Recycling	⊕	⊕
Mobility	●	●
Consumption	⊕	⊕
Covered Obersvations	18	65
Consistent Cases	78.70%	76.47%
Consistency	0.76	0.76
PRI-Value	0.67	0.66
Raw Coverage	0.04	0.08
Unique Coverage	0.04	0.08
Overall Solution Consistency		**0.76**
Overall PRI-Value		**0.67**
Overall Solution Coverage		**0.11**

Note: Black dots indicate the presence of a condition and circles with "⊕" indicate its absence (e.g. Fiss 2010).

Recycling category. Thus, Model 1 underestimated the coverage of the solution paths. For the sample of *Food & Recycling* actions, the solution path (FP1) has a raw coverage of 0.753. It applies to 1872 observations and explains 75.5 percent. For the other categories (Household, Mobility and Other Consumption), the analysis did not yield sufficient solution paths with a consistency above the threshold of 0.74.

The second part of the analysis focused on the question if the Health Information had an impact on a households' willingness to rate an action higher. Therefore, the analysis only included actions with a health effect. A new dummy-condition was introduced to indicate whether households received information about the health co-benefits of an action (1) or not (0). 1935 observations were left. While some participants might have been aware of health co-benefits of specific actions prior to the simulation (e.g. cycling or walking instead of using the car or bus as healthy alternatives), the HOPE-team expected that visually emphasizing the health impact would change the participants' ratings of those actions. Due to the smaller sample, the authors set the consistency value to 0.75 for sufficient conditions and to 0.9 for necessary conditions. The frequency cut off was set to 11, because each household had to rate up to 11 actions that potentially had a positive impact on health. One condition with a negative impact on health was excluded from the analysis.

For this subsample the non-occurrence of the condition *Other Consumption* was necessary for a high willingness in the Likert-rating. This was a foregone conclusion because were no actions with a health effect in the category *Other Consumption*. Overall, two sufficient solution paths were found (Table 4).

The first solution path in this model (HP1) indicates that participants chose actions if they offered no *Economic Benefits*, no *CO_2e-Reduction*, no *Health Information*, required no *Behavioral Change*, and were related to *Mobility*. HP1 has a consistency value of 0.760. The raw and unique coverages are 0.035 each. It applies to 18 observations and explains 78.7 percent of them.

The second solution path (HP2) applies to 68 observations. It has a raw coverage of 0.077. With a consistency, value of 0.762 it explains 76 percent of the observations it covers (52 of 68 observations). For HP2, households were very willing to implement an action with health co-benefits if they received *Health Information* and the action had a positive economic impact, did not necessitate strong *Behavioral Change*, and was part of the *Mobility* category. A substantial decrease in a household's CO_2e-footprint was not required.

The whole solution term has a consistency of 0.767 and a coverage of 0.181. It applies to 98 observations and explains 74 of the 98 observations (75.5 percent).

The authors ran separate QCA analyses for the different consumption categories to compare them to Model 2 (*Food & Recycling, Household, Mobility and Other Consumption*). Only the category *Mobility* included sufficient solution paths. As before, the coverage increased slightly for the solution paths of the separate models. Thus, results were not reported separately but are displayed in the appendix (Table A4). For the solution path (HP1) the coverage increased from 0.035 to 0.084. Additionally, for HP2 the coverage increased from 0.077 to 0.187.

4. Discussion

The discussion will first focus on methodological contributions and limitations and then move to highlight the importance of the results. Given the low coverage of all solution terms, there have to be unobserved conditions that explain the households' Likert ratings. The analyses excluded conditions like socioeconomic characteristics, which may have influenced households' ratings. This is due to the different perspective of this paper. Instead of using households as the unit of analysis, it focused on the individual actions. Moreover, there are methodological reasons for the low coverage. The formula for the coverage of sufficient conditions is the same formula as for the calculation of the consistency for a necessary condition. This means a condition with a high consistency and coverage value for sufficiency tends to be a sufficient and necessary condition. In addition to that, the dummy-conditions for the consumption categories (*Food & Recycling, Household, Mobility and Other Consumption*) lead to an underestimation

of the coverage, because the solution paths can only cover actions that are exclusively part of one of these categories. For example, a solution path that contains the dummy-condition *Household* only covers *Household* actions. *Food & Recycling, Mobility*, and *Other Consumption* actions cannot be part of the same solution path. Therefore, the coverage declines when these conditions are included. The fact that the separate QCAs for each consumption category led to identical solution paths compared to the whole sample shows that mutually exclusive conditions can be used to integrate a subsample analysis in a single QCA-model. This makes it quite similar to a multi-value QCA.

The results from the QCA, the *t*-test (Table 3), and the logistic regression (Appendix; Table A2) suggest that the consumption category influenced the willingness to implement an action in this sample. The majority of households (290) are very willing to implement an action if it does not lead to *Economic Benefits*, does not necessitate strong *Behavioral Change*, and is part of the category *Food & Recycling*. The willingness to realise dietary changes and recycle more can be attributed to the fact that drastic behavioural change is not necessary. Alternatives to meat are often readily available and many European cities use different recycling systems. Additionally, marketing towards locally produced and organic food have spread throughout the food industry over the past few years.

The fact that the negation of *Behavioral Change* is part of P1 is in line with observations from qualitative studies. They suggest that *Behavioral Change* is met with scepticism (Fischer et al., 2011: 1028; Shwom and Lorenzen, 2012: 386). In combination with existing research on the influence of information about negative environmental impacts (Graham and Abrahamse, 2017) or threats to others (Hunter and Röös, 2016) it emphasizes the need for more policies in the areas of food and waste management targeting households.

According to different studies, actions incurring high economic costs are generally associated with lower acceptance by participants (e.g. von Borgstede et al., 2013: 190-91; Drews and van den Bergh, 2016: 13; de Groot & Schuitema, 2012: 105-06; Fischer et al., 2011: 1029; Tobler et al., 2012: 203-04). The design used in this paper was built around financial savings. But the fact that *Economic Benefits* were not determining households' choices does show that financial incentives should not be seen as the most important element of mitigation policies.

The analysis of the health information demonstrates that it can cause households to display a high willingness to implement climate mitigation polices if financial incentives exist. Changing behavior or large CO_2e-reductions are included as negated conditions. Highlighting the health co-benefits of behavior must be considered in future policies. There are marketing strategy that already do this. A campaign on non-motorised mobility in Mannheim used positive imaging about health benefits to encourage people to give up their cars. Contrasting this with the usual strategy of deterring unhealthy behaviour opens up new avenues of addressing households as consumers. Combined with results from a Basque sample on ancillary benefits of mitigation (Longo et al., 2012: 134-35), health co-benefits deserve a closer look in future research and policy designs.

Several conclusions can be drawn: First, Households can potentially realize dietary changes rather quickly and thus contribute to the urgently needed (Bryngelsson et al., 2016; Schleussner et al., 2016) reductions in GHG-emissions to meet NDCs. Second, current structures of consumption and living in developed countries do not make changes in consumption behavior attractive. Third, initiatives that make it possible for households to limit the extent of behavioral change like car, scooter, or bike sharing, an improved public-transport systems, or affordable low-energy housing alternatives can contribute to limit the extent of required behavioral change. Ultimately, policies cannot be limited to financial incentives because it is not the core condition for a willingness to mitigate.

5. Conclusion

This paper investigated necessary and sufficient conditions for European households to adopt climate change mitigation actions and successfully used a mixed-methods design to highlight the strengths and weaknesses of QCA.

It demonstrates how QCA can be used to run a subsample analysis within a single model. Beyond that, it shows that it is reasonable to use different methods as robustness tests instead of only relying on robustness tests within one method. This makes it easier to interpret the results of the QCA. Therefore, future studies are needed to develop a better understanding of best-practices to combine QCA with other methods.

Some solution paths are sufficient for the presence of the outcome *Willingness to Implement an Action*. It is unsurprising that the coverage of the solution paths is low. The authors deliberately did not include most socioeconomic characteristics of people in this study to reduce complexity.

Food & Recycling leads to a higher willingness to mitigate in this sample from four countries. The general pattern that was found shows that people prefer actions that are easy to implement even though they often do not reduce the CO_2e-Footprint by much. Therefore, the condition *Behavioral Change* is the most important lever in improving households' willingness to act on climate change.

Moreover, the analysis of *Health Information* suggests that there is an urgent need to go beyond financial arguments in future research. For example, different ways of visually presenting health co-benefits may result in changing willingness to adopt mitigation actions by households. Because HOPE was the first study to display this information alongside economic impacts and *CO_2e-Reductions*, other studies will hopefully, incorporate this approach to help develop new mitigation policies.

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Conflict of interest

The authors declare that they have no conflict of interest.

Ethical approval and consent to participate

All participants were given written information about the study objectives and modalities (points of assessment, length of questionnaires), data preparation and pseudonymized data storage, the expected amount of commitment, the voluntary nature of participation, and their right to withdraw at any time. Furthermore, participants were informed verbally about the study purpose and procedures and were given the chance to ask questions. All participants provided written informed consent. All countries assure that data processing and storage is done in line with European and national data protection rules. Where necessary the study procedures were approved by an ethical committee. In Norway the Norwegian Center for Research Data approved of the study (44003). In Germany the Institutional Review Board of the Medical Faculty by the University of Heidelberg approved of the study (S-611/2015). In Sweden the study was approved by the Regional Ethical Review Board in Umeå (2015/357-31Ö). In France the project needed to fulfil the obligations of the CNIL (Commission nationale informatique et libertés), no specific ethical approval was necessary.

Data availability

The dataset and R-code used are available in full as electronic supplementary material to this publication.

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Appendix

Table A1
Truth table.

No.	Cost-reduction	CO2e-Reduction	Behavioral Change	Housing	Food & Recycling	Mobility	Other Consumption	Consistency	PRI-Value	n
1	0	0	0	0	1	0	0	0.844	0.793	548
2	0	0	1	0	1	0	0	0.829	0.719	34
3	0	1	1	0	1	0	0	0.818	0.675	1
4	1	0	0	0	1	0	0	0.781	0.673	31
5	0	1	0	0	1	0	0	0.747	0.682	1324
6	0	1	0	0	0	0	1	0.726	0.563	114
7	1	1	0	0	1	0	0	0.72	0.605	170
8	1	0	1	0	1	0	0	0.718	0.612	324
9	1	0	0	0	0	1	0	0.682	0.564	234
10	0	1	0	0	0	1	0	0.669	0.541	85
11	0	1	1	0	0	0	1	0.668	0.424	15
12	0	0	0	0	0	1	0	0.66	0.567	177
13	0	0	0	0	0	0	1	0.633	0.54	1036
14	0	1	1	1	0	0	0	0.629	0.446	5
15	0	0	1	1	0	0	0	0.628	0.521	396
16	1	1	0	0	0	0	1	0.616	0.378	6
17	0	0	0	1	0	0	0	0.609	0.519	629
18	1	0	1	0	0	1	0	0.609	0.389	50
19	1	1	0	0	0	1	0	0.588	0.496	751
20	0	0	1	0	0	1	0	0.578	0.431	125
21	0	0	1	0	0	0	1	0.574	0.378	251
22	1	1	1	0	0	0	1	0.568	0.355	210
23	0	1	0	1	0	0	0	0.543	0.445	809
24	1	0	0	0	0	0	1	0.534	0.384	378
25	1	0	1	0	0	0	1	0.509	0.381	1276
26	1	0	0	1	0	0	0	0.507	0.369	23
27	1	0	1	1	0	0	0	0.492	0.38	736
28	1	1	1	0	1	0	0	0.442	0.316	676
29	0	1	1	0	0	1	0	0.428	0.281	283
30	1	1	1	1	0	0	0	0.424	0.285	407
31	1	1	0	1	0	0	0	0.414	0.279	161
32	1	1	1	0	0	1	0	0.361	0.219	572

Table A2
Logistic Regression Model.

N				11,841
LR Chi^2 (309)				3261.76
Prob > Chi^2				0.000
Pseudo R^2				0.1987
Log likelihood				−6575.382
Modell Specification				Fixed Effects
Variable	Odds Ratio	Standard errors	z	P > |z|
Economic Benefit	1.009*	0.005	1.87	0.061
CO_2e-Reduction	1.089***	0.008	11.53	0.000
Behavioral Change 2	0.392***	0.019	−19.27	0.000
Behavioral Change 3	0.125***	0.012	−21.12	0.000
Household	0.974	0.057	−0.44	0.658
Food & Recycling	2.334***	0.145	13.67	0.000
Mobility	1.18**	0.083	2.31	0.021
Constant	2.981***	1.056	3.08	0.002

Note: Table A2 shows a binary logistic regression model. The willingness to adopt an action was transformed into a binary variable. The variables for *Economic Benefit* and *CO_2e-Reduction* remained uncalibrated. For the variable *Behavioral Change* was included as a categorical variable.

* p < 0.1.
** p < 0.05.
*** p < 0.01.

Table A3
Solution path for the subsample Food.

	Solution
	P1
Attributes of actions	
Economic Benefit	⊕
CO2e-Reduction	
Behavioral Change	⊕
Control Variables	
Household	⊕
Food & Recycling	●
Mobility	⊕
Consumption	⊕
Covered Obersvations	1872
Consistent Cases	75.48%
Consistency	0.75
PRI-Value	0.70
Raw Coverage	0.75
Overall Solution Coverage	0.75
Overall PRI-Value	0.70
Overall Solution Coverage	0.75

Note: Black dots indicate the presence of a condition and circles with "┼" indicate its absence.

Table A4
Solution paths Health Information subsample for the category Mobility.

	Solution	
	HP1	HP2
Attributes of actions		
Economic Benefit	⊕	●
CO2e-Reduction	⊕	⊕
Behavioral Change	⊕	⊕
Health Information	⊕	●
Control Variables		
Household	⊕	⊕
Food & Recycling	⊕	⊕
Mobility	●	●
Consumption	⊕	⊕
Covered Obersvations	18	65
Consistent Cases	78.70%	76.47%
Consistency	0.76	0.76
PRI-Value	0.67	0.66
Raw Coverage	0.08	0.19
Unique Coverage	0.08	0.19
Overall Solution Consistency		0.76
Overall PRI-Value		0.67
Overall Solution Coverage		0.27

Note: Black dots indicate the presence of a condition and circles with "┼" indicate its absence.

Table A5
Whole sample (Table 2, Model 1) calibration willingness 3 = 0.4.

	Solution			
	1	2		3
Attributes of actions				
Economic Benefit	⊕	●		⊕
CO2e-Reduction	⊕	●		●
Behavioral Change	⊕	⊕		⊕
Control Variables				
Household	⊕	⊕		⊕
Food & Recycling	●	●		⊕
Mobility	⊕	⊕		⊕
Consumption	⊕	⊕		●
Consistency	0.85	0.75		0.77
PRI-Value	0.75	0.58		0.56
Raw Coverage	0.14	0.06		0.06
Unique Coverage	0.10	0.02		0.06
Overall Solution Consistency			**0.79**	
Overall PRI-Value			**0.67**	
Overall Solution Coverage			**0.22**	

Note: Black dots indicate the presence of a condition and circles with "┼" indicate its absence.

Table A6
Whole sample (Table 2, Model 1) calibration willingness 3 = 0.6.

	Solution			
	1	2	3	4
Attributes of actions				
Economic Benefit	⊕		●	⊕
CO2e-Reduction		●	⊕	●
Behavioral Change	⊕	⊕	●	●
Control Variables				
Household	⊕	⊕	⊕	⊕
Food & Recycling	●	●	●	⊕
Mobility	⊕	⊕	⊕	⊕
Consumption	⊕	⊕	⊕	●
Consistency	0.74	0.74	0.77	0.78
PRI-Value	0.67	0.65	0.63	0.57
Raw Coverage	0.24	0.19	0.05	0.05
Unique Coverage	0.06	0.02	0.01	0.05
Overall Solution Consistency	**0.83**			
Overall PRI-Value	**0.64**			
Overall Solution Coverage	**0.32**			

Note: Black dots indicate the presence of a condition and circles with "┼" indicate its absence.

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